Three Indexes Estimation in Extracting Change Area from Remote Sensing Image by Fuzzy Theory and Back Propagation Network (BPN)

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***Abstract*- This study presents the technology to combine the remote sensing image of SPOT and FORMOSAT-2 satellite image by Fuzzy theory and Back Propagation Network (BPN). This method adopt three experience identify factors of NDVI, shape, and color to establish the membership function. The fuzzy results show that the successful rate of identification was about 87 percent. The BPN results show that the successful rate of identification was about 91 percent. Therefore the result proves that the three indexes are the best choice in extracting of change area from image, because the error is the lowest among the two methods in this study.**

Keywords*- *Component; Fuzzy Theory; Image Extraction; Image Variation; Image Identification; Back Propagation Network (BPN)

I. INTRODUCTION

The objective of monitoring the change of catchment area is to avoid damage from nature disaster or excessive development. Previous method uses software to identify the build land category, followed by human experience to check it one by one. However, it needs a lot of time to identify image from remote sensing images. If it is possible to automatically study and train the capability of selection system, then the time of distinguish can be effectively reduced.

For example, Meng-Lung Lin and Cheng-Wu Chen used fuzzy model and remote sensing data about Normalized Difference Vegetation Index (NDVI) in the winter, spring, summer, and fall of 2000 and 2005. Their research analyzes land cover maps and landscape sensitivity, and then estimate the sensitivity of the ecosystems in the landscape [1]. Natalie Campos etc., 2011 used High-resolution imagery and find it were successfully assess map changes in land-cover patterns in research area. However, previous these researches in similar area were comparing lacking. They used NDVI image differencing and Classification Tree (CT) methods in their study. Then analyze to connect time with the changes in spatial distribution of mountain resort development (MRD)[2].

Using image segmentation software to produce image segmentation vector and extract the variation region is a common practice for remote sensing technique in the past. The process is: selecting image to segment, outputting the segmentation vector file, using the software to extract the vector layer, and screening for variation area. The work is done by the accumulation of human experience. The memory capability of human can accumulate the previous experience, and it can compile the things touched to the rules of information.

Human brain can trigger the corresponding rules to the next move. If there were no corresponding rules, it can also trigger the fuzzy space for self-learning and reasoning. This capability can be simulated by the case base reasoning with fuzzy theory. Therefore, we use the fuzzy theory and case base reasoning to construct a quantitative fuzzy space structure to learn the human brain logic and estimate the variation region in the remote sensing image.

II. RESEARCH AREA

The research area locates in Shihmen Reservoir in Taoyuan County (Fig. 1). Base on the report (Level 3 Management of Shihmen Reservoir) from Water Resources Agency, Ministry of Economic Affairs, it can be seen that the areas of orchard expand rapidly and mainly spread on sloping fields at altitude of 800 meters which is good for planting temperate fruit trees (peaches) but lower altitude areas are for tangerines. The usage of lands follows by the demand of tourism and economy benefits. It has been a significant change compared with earlier types of crops; therefore it is essential to monitor the environment of Shihmen Reservoir.

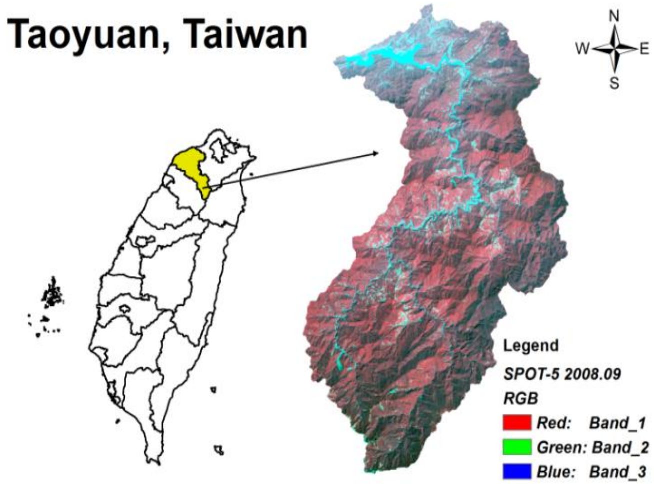

Fig. 1 Shihmen Reservoir

If telemetry can be used to monitor this area, it can quickly browse the full view of reservoir lands and strengthen the ability of monitoring variation region instead of spending great amount of time and money by using manpower. It can improve the traditional way of monitoring to gain efficiency. What's more, there have drafted down some preventive measures of man-made or nature disaster to reduce the influence from disaster and ensure lands can last forever.

III. METHODOLOGY

Three indexes were adopted in this study as experience rules for quick discrimination, they were: differences in NDVI values, shape ratio, and color difference values (Table I and Figs. 2-4).

TABLE Ⅰ MEMBERSHIP FUNCTION AND NUMERICAL VALUE OF THE THREE EVALUATION INDEXES

Evaluation Index of Variation Regional	**Type if Membership Function**	**Attribute if Fuzzy Interval**	**Membership Function Value**
Differences in NDVI Values	Trapezoidal	NDVI Differences Values is Positive	0.3～2
		NDVI No Change	-0.3～0.3
		NDVI Differences Values is Negative	-2～-0.3
Shape Ratio	Trapezoidal	No Change	1 To 1.5 Times
		Diffusion Change	1.5 Times To 10 Times
		Reduction Change	0～1 Time
Color Difference Value	Trapezoidal	Similar	-30～30
		Dissimilar, Positive Value	30～765
		Dissimilar, Negative Value	-765～-30

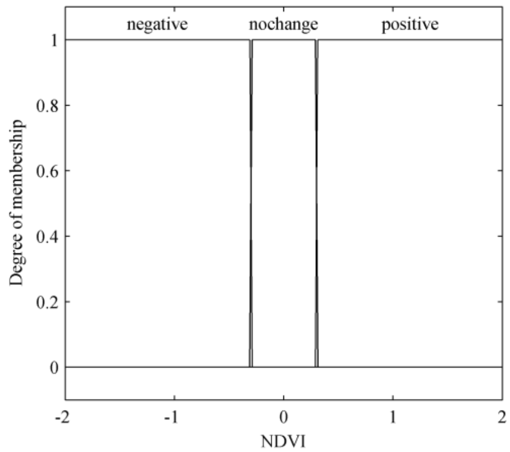

Fig. 2 Differences in NDVI values

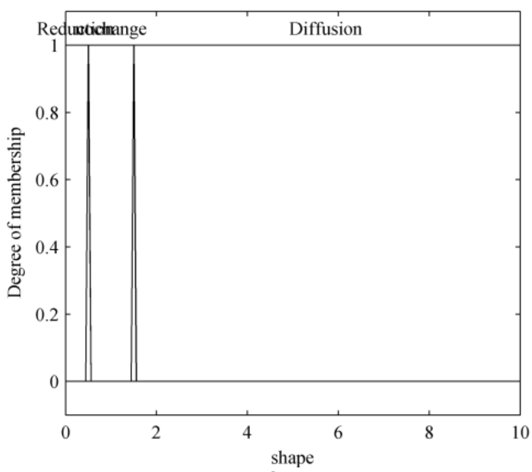

Fig. 3 Shape ratio

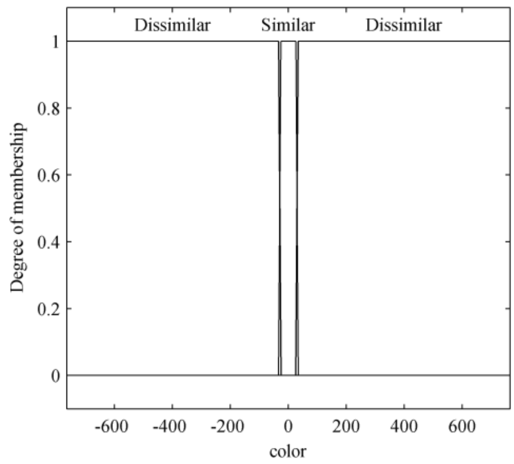

Fig. 4 Color difference values

A. Differences in NDVI Values

Chao-Yuan Lin etc., 2010 used multi-temporal satellite images index (NDVI) to automatically extract landslide and image classification. Usually, image classification uses NDVI to increase accuracy. Because it can effective to classify the bare land and vegetation cover [3].The α value, NDVI [4], is to use the characteristic of green plant which can absorb the red light and reflect the near red wave. According to wave length from the remote sensing data, it can provide the plant growth trend for the variation area. The meaning of NDVI value difference is to compare the ratio of red light absorption and near-infrared light reflection by green plant in the remote sensing image. The numerical value of NDVI difference is the difference of the early image and late image. Its value was ranged between -2～2.

1) Define the NDVI value of previous image is a, and the value of post-image is b. The range of a single NDVI value is between -1~1.

2) Let f(a) = {1,-1} f(b)= {-1,1} ,then f(b)-f(a) = -2 and 2 , so the maximum threshold value is between -2~2.

3) The different value of NDVI is in the range between -2~2. According to the induction of manual experience, if the difference value of NDVI is lower than 0.3, it could be regarded as having no change.

4) Let f(a)= {0.2,0.5} f(b)= {0.5,0.2} , we set the range as if the value is between -0.3 ~ 0.3, then there is no change. If the value is between 0.2~0.3, then there is change.

The function of NDVI is to rapidly analyze the plant growth rate in the variation region. Otsu has proposed a rule for plant in the remote sensing image in 1979[5].The color value of image was divided into two areas as vegetation and non-vegetation.

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \tag{1}$$

Where, NIR is the near infrared band and R is the red band.

B. Shape Ratio

The shape ratio (α β) is the area after the event divided by the area before the event. The outer shape is used to analyze whether it has achieved the variation, as shown in Fig. 5.

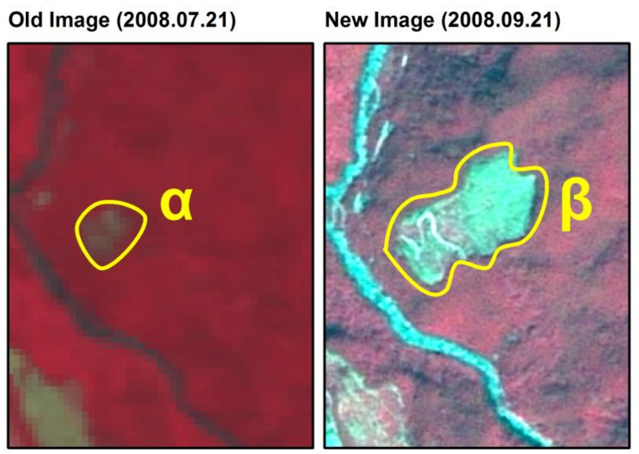

Fig. 5 Shape ratio

The definition of shape ratio is the ratio of post stage area to the previous stage area. It has to be assigned with the value according to the error factors of location, shape, and twist, etc. If the value is lower than 1, it is the reduction change. If the value is 1 to 1.5, then there is no change. If the value is greater than 1.5, then it is the diffusion change.

The shape ratio is not applicable to the land use type as: from never to have, from having to no, and the simplest change of type. The shape ratio is applicable to the condition when the land use types have no change, and only the area shape changes. The shape ratio is also applicable to the area which has been labeled as the variable region.

$$Shape = \frac{(\beta - \alpha)}{(\alpha)} \tag{2}$$

C. Color Difference Values

The color difference is the color before and after the event. In any pixel of the remote sensing data, the maximum value of RGB will not exceed 255+255+255 = 765, as shown in Fig. 6.

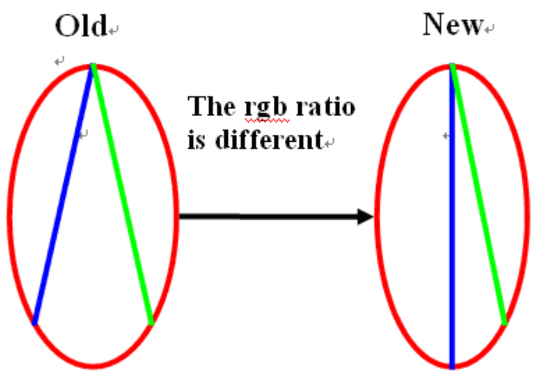

Fig. 6 Color difference values

IV. CONSTRUCT FUZZY

The MATLAB fuzzy toolbox was used to construct a structure of rapid extraction. Three groups of indicators were identified. The functional forms and membership function value were shown in Figs. 4~7. Since every index has three attribute of fuzzy interval. So every index has four critical ranges. Kaufmann and Gupta [6] induced several types of membership function. Most suitable for all indexes is the trapezoidal fuzzy number defined as:

$$f(x,a,b,c,d) = \begin{cases} 0 & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \frac{d-x}{d-c} & c \le x \le d \\ 0 & x \ge d \end{cases}$$

$$a \le b, c \le d$$

The trapezoidal function was chosen in this study because the interval of threshold value for the three indexes in this study is relatively fixed. Twenty seven rules of < IF…THEN > were formulated as the following:

1) If (NDVI is no change) and (shape is no change) and (color is Similar) then (expected value is no change)

2) If (NDVI is no change) and (shape is no change) and (color is Dissimilar) then (expected value is yes change)

3) If (NDVI is no change) and (shape is no change) and (color is Dissimilar) then (expected value is yes change)

4) If (NDVI is no change) and (shape is Reduction) and (color is Similar) then (expected value is yes change)

5) If (NDVI is no change) and (shape is Reduction) and (color is Dissimilar) then (expected value is yes change)

6) If (NDVI is no change) and (shape is Reduction) and (color is Dissimilar) then (expected value is yes change)

7) If (NDVI is no change) and (shape is Diffusion) and (color is Similar) then (expected value is yes change)

8) If (NDVI is no change) and (shape is Diffusion) and (color is Dissimilar) then (expected value is yes change)

9) If (NDVI is no change) and (shape is Diffusion) and (color is Dissimilar) then (expected value is yes change)

10) If (NDVI is negative) and (shape is no change) and (color is Similar) then (expected value is yes change)

11) If (NDVI is negative) and (shape is no change) and (color is Dissimilar) then (expected value is yes change)

12) If (NDVI is negative) and (shape is no change) and (color is Dissimilar) then (expected value is yes change)

13) If (NDVI is negative) and (shape is Reduction) and (color is Similar) then (expected value is yes change)

14) If (NDVI is negative) and (shape is Reduction) and (color is Dissimilar) then (expected value is yes change)

15) If (NDVI is negative) and (shape is Reduction) and (color is Dissimilar) then (expected value is yes change)

16) If (NDVI is negative) and (shape is Diffusion) and (color is Similar) then (expected value is yes change)

17) If (NDVI is negative) and (shape is Diffusion) and (color is Dissimilar) then (expected value is yes change)

18) If (NDVI is negative) and (shape is Diffusion) and (color is Dissimilar) then (expected value is yes change)

19) If (NDVI is positive) and (shape is no change) and (color is Similar) then (expected value is yes change)

20) If (NDVI is positive) and (shape is no change) and (color is Dissimilar) then (expected value is yes change)

21) If (NDVI is positive) and (shape is no change) and (color is Dissimilar) then (expected value is yes change)

22) If (NDVI is positive) and (shape is Reduction) and (color is Similar) then (expected value is yes change)

23) If (NDVI is positive) and (shape is Reduction) and (color is Dissimilar) then (expected value is yes change)

24) If (NDVI is positive) and (shape is Reduction) and (color is Dissimilar) then (expected value is yes change)

25) If (NDVI is positive) and (shape is Diffusion) and (color is Similar) then (expected value is yes change)

26) If (NDVI is positive) and (shape is Diffusion) and (color is Dissimilar) then (expected value is yes change)

27) If (NDVI is positive) and (shape is Diffusion) and (color is Dissimilar) then (expected value is yes change)

The fourth stage investigation data from the project of SWCB-97-157 in 2008 were taken as the experience cases. Ho-Wen Chen etc., 2009 developed a neural-fuzzy inference approach with used the FORMOSAT-2 (8m spatial resolution) multi-spectral satellite image. It can to analysis the land use and land cover patterns in a fast growing city. Their each fuzzy-neural rule incorporated with both the satellite image spectral and textural features. So, it increased the advantages of classification efficiency and accuracy [7].

However, in this paper try to use better high resolution satellite fusion images (FORMOSAT-2 2m spatial resolution and SPOT) with three indexes, the results were further verified. The expected value of variations was calculated by the module and obtains the value of 0.67. The module chart is shown in Fig. 7. It means that if there is a possibility of change, its value will be greater than 0.67. Otherwise, the value of change will be lower than 0.67. The results of experience cases were shown in Table II, Ⅲ. From the table results, there are three cases with the expected value of variance lower than 0.67 among the 32 cases. So the success rate of distinguish is (55-7)/55=0.87. The recognition rate is about 87%.

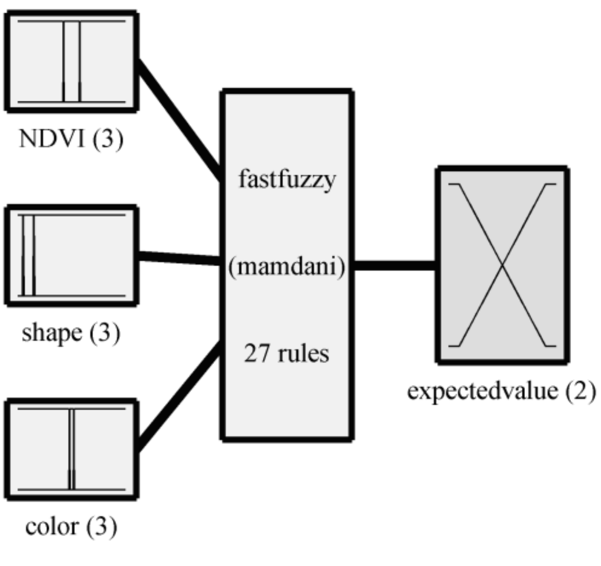

Fig. 7 Module chart

TABLE Ⅱ THE THIRD EXPERIENCE CASE IN 2008

No	Differences in NDVI Values	Shape Ratio	Color Difference Value	Expected Value of Variations
C1	-0.29	1	89	0.67
C2	-0.28	1	160	0.67
C3	-0.15	1	-62	0.67
C4	0.43	1	-83	0.67
C5	-0.42	1	127	0.67
C6	0.01	1	65	0.67
C7	-0.08	1	6	0.33
C8	-0.09	1	133	0.67
C9	-0.06	5.66	-25	0.67
C10	0.05	1.86	-6	0.67
C11	0.08	1	-22	0.33
C12	0.19	1	-96	0.67
C13	0.30	1	-111	0.67
C14	0.07	1	-85	0.67
C15	0.27	1	29	0.33
C16	0.25	1	73	0.67
C17	0.16	1	45	0.67
C18	0.18	1	13	0.33
C19	0.08	2.97	66	0.67
C20	0.25	1	-53	0.67
C21	0.15	1	-73	0.67
C22	-0.17	1	171	0.67

TABLE Ⅲ THE FOURTH EXPERIENCE CASE IN 2008

No	Differences in NDVI Values	Shape Ratio	Color Difference Value	Expected Value of Variations
D1	-0.25	1.00	-128.00	0.67
D2	-0.63	1.00	-3.00	0.67
D3	-0.62	1.00	-13.00	0.67
D4	-0.47	1.00	-22.00	0.67
D5	-0.22	1.00	-93.00	0.67
D6	-0.34	1.00	-53.00	0.67
D7	-0.50	1.00	-1.00	0.67
D8	-0.38	2.56	-26.00	0.67
D9	-0.14	1.00	-90.00	0.67
D10	-0.42	1.00	-35.00	0.67
D11	-0.10	1.00	-47.00	0.67
D12	-0.40	1.00	29.00	0.67
D13	-0.35	1.00	66.00	0.67
D14	-0.51	1.00	10.00	0.67
D15	-0.54	1.00	-16.00	0.67
D16	-0.42	1.00	-14.00	0.67
D17	-0.58	1.00	-38.00	0.67
D18	-0.44	1.00	-23.00	0.67
D19	-0.30	1.00	-12.00	0.5
D20	-0.44	1.00	20.00	0.67
D21	-0.41	1.00	-100.00	0.67
D22	-0.35	1.00	15.00	0.67
D23	-0.27	1.00	-92.00	0.67
D24	-0.22	1.00	-62.00	0.67
D25	-0.42	1.00	41.00	0.67
D26	-0.56	1.00	-75.00	0.67
D27	-0.56	1.00	-40.00	0.67
D28	-0.43	1.00	-20.00	0.67
D29	-0.45	1.00	-47.00	0.67
D30	-0.28	1.00	-19.00	0.33
D31	-0.30	1.00	26.00	0.5
D32	-0.57	1.00	-3.00	0.67
D33	-0.05	1.00	-104.00	0.67

V. NEURAL NETWORK MODEL

One neural network model, the Back Propagation Network (BPN) was used in this study to find the best results [8]. The experimentation data of BPN are to the real value (Table Ⅳ).

TABLE Ⅳ THE THIRD AND FOURTH ERROR RANGE

No	Differences in NDVI Values	Shape Ratio	Color Difference Values	Assessment Index	Expected Value	Error Range (%)
C1	-0.29	1	89	19.73	19.51	1.14%
C2	-0.28	1	160	24.12	23.52	2.50%
C3	-0.15	1	-62	14.47	15.43	6.66%
C4	0.43	1	-83	22.84	19.36	15.24%
C5	-0.42	1	127	25.47	24.48	3.86%
C6	0.01	1	65	11.17	11.84	6.03%
C7	-0.08	1	6	9.06	12.62	39.30%
C8	-0.09	1	133	17.61	17.12	2.77%
C9	-0.06	5.66	-25	40.87	34.97	14.44%
C10	0.05	1.86	-6	14.04	14.60	3.95%
C11	0.08	1	-22	10.10	12.83	26.99%
C12	0.19	1	-96	17.69	18.86	6.62%
C13	0.3	1	-111	21.42	20.85	2.65%
C14	0.07	1	-85	13.97	17.28	23.67%
C15	0.27	1	29	15.31	10.60	30.78%
C16	0.25	1	73	17.69	9.79	44.65%
C17	0.16	1	45	13.61	10.46	23.11%
C18	0.18	1	13	12.02	11.21	6.72%
C19	0.08	2.97	66	26.11	25.88	0.90%
C20	0.25	1	-53	16.38	15.50	5.39%
C21	0.15	1	-73	15.19	16.65	9.66%
C22	-0.17	1	171	22.09	21.80	1.33%
D1	-0.25	1	-128	21.28	19.87	6.64%
D2	-0.63	1	-3	22.61	23.69	4.77%
D3	-0.62	1	-13	23.02	23.22	0.90%
D4	-0.47	1	-22	19.85	19.31	2.73%
D5	-0.22	1	-93	18.25	17.53	3.92%
D6	-0.34	1	-53	18.63	16.75	10.08%
D7	-0.5	1	-1	19.23	20.59	7.07%
D8	-0.38	2.56	-26	28.27	28.54	0.96%
D9	-0.14	1	-90	16.05	17.19	7.12%
D10	-0.42	1	-35	19.45	18.02	7.35%
D11	-0.1	1	-47	12.24	14.45	18.06%
D12	-0.4	1	29	18.56	19.16	3.24%
D13	-0.35	1	66	19.73	19.72	0.04%
D14	-0.51	1	10	20.07	21.21	5.70%
D15	-0.54	1	-16	21.21	21.19	0.13%
D16	-0.42	1	-14	18.08	18.27	1.02%
D17	-0.58	1	-38	23.65	21.77	7.94%
D18	-0.44	1	-23	19.17	18.58	3.07%
D19	-0.3	1	-12	14.95	15.75	5.32%
D20	-0.44	1	20	18.97	19.81	4.43%
D21	-0.41	1	-100	23.45	19.25	17.90%
D22	-0.35	1	15	16.40	17.37	5.91%
D23	-0.27	1	-92	19.43	17.68	9.00%
D24	-0.22	1	-62	16.22	15.80	2.59%
D25	-0.42	1	41	19.85	20.23	1.93%
D26	-0.56	1	-75	25.57	21.21	17.05%
D27	-0.56	1	-40	23.28	21.25	8.71%
D28	-0.43	1	-20	18.72	18.39	1.76%
D29	-0.45	1	-47	20.99	18.65	11.14%
D30	-0.28	1	-19	14.91	15.39	3.20%
D31	-0.3	1	26	15.87	16.55	4.34%
D32	-0.57	1	-3	21.11	22.28	5.53%
D33	-0.05	1	-104	14.71	18.36	24.80%
Mean						8.96%

A. *Training and Test Model*

In this mode, the original data was used to establish the model. The input was the unit for training, the number of hidden layer, learning cycle, and speed of learning cycle, etc.

B. *Authentication Model*

The authentication mode is to use the non-training data to evaluate the reliability of the model. The results can be the information of the scattering plot, matrix, or error analysis. The output variable will also be estimated to compare their error.

C. *Inference Model*

The inference model is used to predict certain condition that we want to know. The experienced value was derived from the trained mode. (citation : http://www.wisdomsoft.com.tw)

The value of assessment index is calculated as the following:

$$assessmentindex = \frac{(Differences\ in\ NDVI\ values)}{4} \times 100 + \frac{(Shape\ ratio)}{15} \times 100 + \frac{(Color\ difference\ value)}{1530} \times 100 \tag{3}$$

The prediction results of these BPN neural network schemes were shown in (Table IV).The error of BPN to the real value is 91.04%.

VI. CONCLUSION

It is necessary to appropriately monitor the environment according to the characteristic of land use in the watershed. Remote sensing technology helps to provide the real time data, and can quickly glimpse the land picture status of watershed.

This technology enforces the capability of variation region monitoring, and could save time and cost. The result reveals that the FUZZY and BPN have better feasibility of predictive values, which proves that the three index is better choice in extracting change area from image. Therefore, we will use this experience to identify factors of NDVI, shape, and color to establish the membership function basic module for further research.

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